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SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,312,122,** on June 23, 2000, by **GFI CONTROL SYSTEM INC.,** assignee of Erick Girouard, for "Gas Flow Regulation System".

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ABSTRACT

A gas flow regulation module comprising, a body, including a longitudinal axis, and including a first port and second port, a first fluid passage extending from the first port, and a second fluid passage extending from the second port; and a regulator, mounted to the body and disposed in communication with the first and second fluid passages, including a moveable pressure boundary member characterized by a transverse axis which is substantially perpendicular to the longitudinal axis of the neck. A gas flow regulation module, adapted for mounting within a pressure vessel and through an aperture provided in the pressure vessel, the pressure vessel including an interior, the aperture including a longitudinal axis, comprising, a body, including a first port and a second port, a first fluid passage extending from the first port and a second fluid passage extending from the second port, and a regulator mounted to the body and disposed in the interior of the pressure vessel and in communication with the first and second fluid passages, including a moveable pressure boundary member characterized by a transverse axis which is perpendicular to the longitudinal axis of the aperture.

GAS FLOW REGULATION SYSTEM

FIELD OF INVENTION

The present invention relates to gas flow regulation systems for controlling the flow of gas, and more particularly relates to tank-mounted modules for controlling the flow of high pressure gaseous fuels such as compressed or liquified natural gas or hydrogen from a storage tank.

BACKGROUND OF THE INVENTION

It is becoming increasingly common to use so-called alternative fuels, such as propane or natural gas, in internal combustion engines or hydrogen in fuel cells. Often such engines are converted to use one or two or more sources of fuel, such as gasoline and natural gas. The operator has the ability to switch between sources depending on the availability and price of these fuels.

Many vehicles are manufactured to operate on gasoline only and are converted to run on two or more fuels. The vehicles are manufactured with storage tanks for gasoline, pumps for moving the gasoline from the tank to the engine, and carburetors or fuel injectors for introducing the fuel and the required amount of air for combustion into the engine.

Gaseous fuels such as propane, natural gas, and hydrogen must be stored in pressurized cylinders to compress the gas into a manageable volume. Increasing the pressure to the highest level that can safely be handled by the pressurized storage cylinder increases the amount of fuel that can be stored in that cylinder and extends the distance that the vehicle can be driven to its maximum. Typical storage cylinder pressures range from 2000 to 5000 psig.

Internal combustion engines cannot operate at such a high pressure, and the pressure of the gas must be reduced to a level at which the engine can be operated safely.

The pressure must also be regulated as it is reduced to ensure that the pressure of the fuel entering the engine is nearly constant even as the pressure in the storage cylinder is reduced. At the same time, the pressure regulation must permit as much gas as possible to be removed from the

storage cylinder, and thus permit the pressure in the storage cylinder to fall to as close to the operating pressure as possible. A high pressure difference across the pressure regulator means that unused fuel remains in the storage cylinder and is unavailable to the engine.

Conventional pressure regulators having one or more stages over which the pressure is reduced are well-known and have long been used to reduce the pressure and regulate the flow of compressed gases. Some of these are known as pressure-balanced regulators and use various arrangements of springs, diaphragms and machined parts to balance pressures and fluid flow over the various stages of the regulator.

One major concern is the vulnerability of flow components carrying alternate fuels, including pressure regulators, to crash damage. If the vehicle is involved in an accident, such components must not fail in an unsafe or catastrophic manner. To this end, internally-mounted pressure regulators have been designed to mitigate such unsafe or catastrophic conditions. An example of such pressure regulators is disclosed in Sirosh et al., U.S. Patent 6,041,762.

Although Sirosh's pressure regulator can be internally mounted within a single nozzle in a storage cylinder, the space occupied by such regulator prevents, as a practical matter, the further internal mounting of a solenoid shut off valve within the same nozzle to open and close flow to the pressure regulator or the further internal mounting of a second regulator stage. The size of the nozzle could be increased to accommodate the solenoid shut off valve or a second regulator stage. However, such design changes would reduce the pressure rating of the associated storage cylinder, thereby preventing its use in storing high pressure gases.

SUMMARY OF THE INVENTION

In a broad aspect, the present invention provides a gas flow regulation module comprising a body, including a longitudinal axis, and including a first port and second port, a first fluid passage extending from the first port, and a second fluid passage extending from the second port, and a regulator, mounted to the body and disposed in communication with the first and second fluid

passages, including a moveable pressure boundary member characterized by a transverse axis which is substantially perpendicular to the longitudinal axis of the neck. The regulator can include, a housing with an internal surface, a pintle chamber and an output chamber, a moveable pressure boundary member extending across the internal surface of the house, a valve seat, including an orifice, wherein the pintle chamber can communicate with the output chamber via the orifice, and a pintle valve, mounted to the movable pressure boundary member, and including a sealing member, and moving into contact with the valve seat to thereby close the orifice and isolate the pintle chamber from the output chamber. The regulator can comprise at least two stages. The moveable pressure boundary member can be a diaphragm assembly. The gas flow regulation module can further comprise a solenoid shut-off valve, mounted to the body, and including a sealing member for closing the second port. The gas flow regulation module can further comprise a third port extending to the second port via a third fluid passage.

In another aspect, the present invention provides a gas flow regulation module comprising, a body, including a longitudinal axis, and further including a first port and a second port, a first fluid passage extending from the first port, and a second fluid passage extending from the second port, and a regulator, mounted to the body and disposed in communication with the first and second fluid passages, including a moveable pressure boundary member substantially disposed in a plane which is substantially parallel to the longitudinal axis of the neck.

In a further aspect, the present invention provides a gas flow regulation module, adapted for mounting within a pressure vessel and through an aperture provided in the pressure vessel, the pressure vessel including an interior, the aperture including a longitudinal axis, comprising a body, including a first port and a second port, a first fluid passage extending from the first port and a second fluid passage extending from the second port, and a regulator mounted to the body and disposed in the interior of the pressure vessel and in communication with the first and second fluid passages, including a moveable pressure boundary member characterized by a transverse axis which is perpendicular to the longitudinal axis of the aperture.

In yet a further aspect, the present invention provides, a gas flow regulator module, adapted for mounting within a pressure vessel, and through an aperture provided in the pressure vessel, the pressure vessel including an interior, a longitudinal axis, comprising a body, including a first and a second port, a first fluid passage extending from the first port, and a second fluid passage extending from the second port, and a regulator mounted to the body and disposed in the interior of the pressure vessel and in communication with the first and second fluid passages, the regulator including a moveable pressure boundary member substantially disposed in a plane which is substantially parallel to the longitudinal axis of the aperture.

By operating the moveable pressure boundary of the regulator in this manner, the module can further include a solenoid shut-off valve or a second regulator stage without requiring large nozzles to fit such an assembly in the interior of a pressure vessel.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and objects other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings wherein:

Figure 1 is a side elevation view of an embodiment of the system of the present invention showing the system installed in a pressure vessel;

Figure 2 is a top plan view of the system of the present invention illustrated in Figure 1;

Figure 3 is a sectional elevation view of a regulator of the system of the present invention illustrated in Figure 1;

Figure 4 is a cut-away sectional elevation view of the pressure regulator in Figure 3, showing components in the vicinity of the convolution of the diaphragm;

Figure 5 is a sectional elevation view of the system of the present invention illustrated in Figure 1 showing the system installed in a pressure vessel;

Figure 6 is a cut-away sectional elevation view of the regulator in Figure 5, showing each of the individual stages of the regulator;

Figure 7 is a second sectional elevation view of the system of the present invention illustrated in Figure 1 showing the system installed in a pressure vessel;

Figure 8 is a sectional elevation view of the solenoid shut-off valve of a system of the present invention illustrated in Figure 1 showing the solenoid shut-off valve in a closed position;

Figure 9 is a sectional elevation view of the solenoid shut-off valve of the system of the present invention illustrated in Figure 1 showing the shut-off valve in a transition position;

Figure 10 is a sectional elevation view of the solenoid shut-off valve of the system of the present invention illustrated in Figure 1 showing the shut-off valve in an open position;

Figure 11 is a schematic showing the flow path taken through a shut-off valve of the present invention during filling of a pressure vessel with a gaseous mixture;

Figure 12 is a schematic drawing showing manual shut-off valve blocking floor between a solenoid shut-off valve and a regulator of a system of the present invention;

Figure 13 is a sectional plan view of the system of the present invention illustrated in Figure 1; and

Figure 14 is a schematic illustration of the process flow paths provided in the system of the present invention illustrated in Figure 1.

DETAILED DESCRIPTION

Figure 1 illustrates an embodiment of a gas flow regulation module (2) of the present invention. Module (2) comprises a body (3) including a head (4) and a neck (6). Pressure regulators (10) and (110), and solenoid shut off valve (210) are formed within neck (6) to control flow of gas from a pressure vessel (216).

Referring to **Figures 3 and 4**, pressure regulator (10) includes spring housing (12) mounted to base (14) to form regulator housing (16). Housing (16) includes an inlet port (18) communicating with a pintle chamber (20). Pintle chamber (20) communicates with output chamber (22) and includes a valve seat (23) with orifice (24). Valve pintle (26) is disposed within pintle chamber (20) and includes sealing surface (28) to press against valve seat (23) and thereby close orifice (24). Output chamber (22) communicates with outlet port (25) formed within housing (16) (see Figure 5).

Valve pintle (26) is movable to open and close orifice (24) in response to the combined action of spring (30) and moveable pressure boundary member (31). Spring (30) is provided within housing (16) to exert a force which tends to move the valve pintle (26) towards an open position wherein sealing surface (28) is unseated from valve seat (23), thereby opening orifice (24) into communication with output chamber (22). Gas pressure in pintle chamber (20) and output chamber (22) acts against moveable pressure boundary member (31) and valve pintle (26) thereby opposing forces exerted by spring (30) and tending to move valve pintle (26) towards a closed position, wherein sealing surface (28) is pressed against valve seat (23), thereby closing orifice (24). Pintle stem (34) extends from valve pintle (26), terminating in pintle nut (36). Pintle nut (36) is mounted within central boss (38). Central boss (38) extends through the centre of moveable pressure boundary (31). A locking ring (44) fits over central boss (38) and bears down upon moveable pressure boundary member (31).

Spring (30) is fitted over locking ring (44), and is supported on moveable pressure boundary member (42). Spring (30) is retained within a spring chamber (46) formed within housing (16). Spring (30) can include coil springs, spring washers, or elastomeric-type springs.

In one embodiment, moveable pressure boundary member is a diaphragm assembly comprising a diaphragm (32), first diaphragm plate (40) and diaphragm support plate (42). Diaphragm (32) is mounted on a first diaphragm plate (40) disposed on one side of diaphragm (32) and extending from central boss (38). The diaphragm (32) is retained on the first diaphragm plate (40) by means of a diaphragm support plate (42) and a locking ring (44). As such, diaphragm (32) is interposed and pinched between first diaphragm plate (40) and diaphragm support plate (42). Groove (48) is formed within housing (16) to receive diaphragm (32), thereby securing diaphragm (32) to housing (16). In this respect, diaphragm (32) seals output chamber (22) from spring chamber (46), thereby isolating output chamber (22) from spring chamber (46). Diaphragm (32) is generally characterized by a flat profile. Diaphragm (32) includes a first side surface (56) and second side surface (58) (see Figure 4). First side surface (56) is exposed to gas within output chamber (22). Diaphragm (32) further includes a throughbore (60) which receives central boss (38). In one embodiment, diaphragm (32) includes a rolling convolution (50) extending from a section (52) characterized by a flat profile, to provide a modification in the behaviour of diaphragm (32). Specifically, this design attempts to ensure that diaphragm (32) is always in tension (i.e., never in shear or compression). Thus, as the convolution rolls, diaphragm (32) is never stretched or buckled (i.e., largely eliminating hysteresis).

Pressure regulator (10) is characterized by an orientation wherein the transverse axis (61) of moveable pressure boundary member (31) is substantially perpendicular to the longitudinal axis (62) of neck (6) (see Figure 1). As a further incident, moveable pressure boundary member (31) lies or is disposed substantially in a plane which is parallel to the longitudinal axis (62) of neck (6). Such orientation permits the use of a relatively larger diameter moveable pressure boundary member (31) within module (2) where it is desired to minimize the diameter or width of neck (6). Use of larger diameter moveable pressure boundary members (31) in pressure regulators is desirable so that the pressure boundary member is more sensitive to pressure changes in the output chamber (22), thereby providing a more accurate response to these pressure changes and mitigating droop. Because moveable pressure boundary member (31) is oriented in this fashion, more space is available within

module (2) for the formation of various flow passages necessary for permitting internal mounting of a solenoid shut-off valve (210) in conjunction with a regulator.

Output port (25) can be adapted to communicate with an inlet port (118) of a second stage pressure regulator (110), as illustrated in Figures 5 and 6. In one embodiment, pressure regulator (110) is a balanced pressure regulator. Pressure regulator (110) includes spring housing (112) mounted to base (114) to form regulator housing (116). Housing (116) includes an inlet port (118) communicating with a pintle chamber (120). Pintle chamber (120) communicates with output chamber (122) and includes a valve seat (123) with orifice (124). Valve pintle (126) is disposed within pintle chamber (120) and includes a sealing member (127) with a sealing surface (128) to press against valve seat (123) and thereby close orifice (124). Output chamber (122) communicates with output port (123) formed within housing (116).

Valve pintle (126) is movable to open and close orifice (124) in response to the combined action of spring (130) and diaphragm (132). Spring (130) is provided within housing (116) to exert a force which tends to move the valve pintle (126) towards an open position wherein sealing surface (128) is unseated from valve seat (123), thereby opening orifice (124) into communication with output chamber (122). Gas pressure in pintle chamber (120) and output chamber (122) acts against moveable pressure boundary member (131) and valve pintle (126) thereby opposing forces exerted by spring (130) and tending to move valve pintle (126) towards a closed position, wherein sealing surface (128) is pressed against valve seat (123), thereby closing orifice (124). Pintle stem (134) extends from valve pintle (126), terminating in pintle nut (136). Pintle nut (136) is mounted within central boss (138). Central boss (138) extends through the centre of moveable pressure boundary member (131). A locking ring (144) fits over central boss (138) and bears down upon moveable pressure boundary member (131).

Pressure regulator (110) is a balanced regulator with features provided to mitigate pressure imbalances which are attributable to unsteady state conditions, such as source pressure variability in pintle chamber (120). In this respect, regulator (110) is further provided with a balancing chamber

(170) extending and sealed from pintle chamber (120). Valve pintle (126) includes balancing stem (172) extending from sealing member (127) and disposed within balancing chamber (170). Valve pintle (126) further includes a throughbore (174) extending between ports (176) and (178) provided in the surface of valve pintle (126). Port (176) opens into communication with output chamber (122). Port (178) opens into communication with balancing chamber (170). Balancing chamber (170) is sealed from pintle chamber (120) by sealing member (180), such as an o-ring, which is carried within a groove (182) provided within internal surface (184) of balancing chamber (170). By virtue of this arrangement, balancing chamber (170) is in direct communication with output chamber (122). To mitigate the effects of pressure variability within pintle chamber (120) on the regulation of pressure by the combined action of diaphragm assembly (131) and valve pintle (126), the cross-sectional area of balancing stem is made substantially the same as the seating area of sealing surface (128). This substantially reduces the significance of pressure in pintle chamber (120) on the regulatory function of diaphragm assembly (131) and valve pintle (126).

Spring (130) is fitted over locking ring (144), and is supported on diaphragm support plate (142). Spring (130) is retained within a spring chamber (146) formed within housing (116). Spring (130) can include coil springs, spring washers, or elastomeric-type springs.

In one embodiment, moveable pressure boundary member (131) is a diaphragm assembly comprising diaphragm (132), first diaphragm plate (140), and diaphragm support plate (142). Diaphragm (132) is mounted on a first diaphragm plate (40) disposed on one side of diaphragm (132) and extending from central boss (138). The diaphragm (132) is retained on the first diaphragm plate (140) by means of a diaphragm support plate (142) and a locking ring (144). As such, diaphragm (132) is interposed and pinched between first diaphragm plate (140) and diaphragm support plate (142). Groove (148) is formed within housing (116) to receive diaphragm (132), thereby securing diaphragm (132) to housing (116). In this respect, diaphragm (132) seals output chamber (122) from spring chamber (146), thereby isolating output chamber (122) from spring chamber (146). Diaphragm (132) is generally characterized by a flat profile. Diaphragm (132) includes a first side surface (156) and second side surface (158). First side surface (156) is exposed

to gas within output chamber (122). Diaphragm (132) further includes a throughbore (160) which receives central boss (138). In one embodiment, diaphragm (132) includes a rolling convolution (150) extending from a section (152) characterized by a flat profile, to provide a modification in the behaviour of diaphragm (132). Specifically, this design attempts to ensure that diaphragm (132) is always in tension (i.e., never in shear or compression). Thus, as the convolution rolls, diaphragm (132) is never stretched or buckled (i.e., largely eliminating hysteresis)

Like pressure regulator (10), pressure regulator (110) is characterized by an orientation wherein transverse axis (161) of moveable pressure boundary member (131) is substantially perpendicular to longitudinal axis (62) of neck (6). As a further incident, moveable pressure boundary member (131) lies or is disposed substantially in a plane which is parallel to the longitudinal axis (62) of neck (6). Such orientation permits the use of a relatively larger moveable pressure boundary member (132) within module (2) where it is desired to minimize the diameter or width of neck (6). Use of larger diameter moveable pressure boundary members (131) in pressure regulators is desirable so that the pressure boundary member is more sensitive to pressure changes in the output chamber (122), thereby providing a more accurate response to these pressure changes and mitigating droop. Because moveable pressure boundary member (131) is oriented in this fashion, more space is available within module (2) for the formation of various flow passages necessary for permitting internal mounting of a solenoid shut-off valve in conjunction with a regulator.

In one embodiment an adjustable member, such as a screw (164), is provided and extends through housing (116) to regulate compression of associated spring (130), thereby varying flow control characteristics of valve pintle (126).

A vent passage (84) is also formed within housing (16) to communicate with spring chamber (46). Any gas leaking across diaphragm (3) from output chamber (22) and into spring chamber (46) is thereby vented to prevent accumulation of gas within spring chamber (46). Where pressure regulation is accomplished by first and second stage regulators (10) and (100) in series, spring

chamber (46) of first stage regulator (10) vents to output chamber (122) of second stage regulator (110), while spring chamber (146) of second stage regulator (110) vents via passage (184) to atmosphere via port (316) formed within head (4).

In one embodiment, gas within vessel (216) is characterized by a pressure of about 5000 psig. As gas flows across first stage regulator (10), pressure is dropped to about 300 to 500 psig. Pressure is further reduced through second stage regulator (110) such that pressure in output chamber (122) is about 115 psig.

Referring to **Figures 5, 13 and 14**, gas flowing from a second stage regulator (110) through outlet port (125) is connected to outlet passage (300) which communicates with outlet port (310) formed within head (4). Optionally connected to outlet passage (300) is a pressure relief device (312) installed in port (314) in head (4). Pressure relieve device (312) vents to a relief outlet connection (313).

Sensor ports (318) and (320) can also be formed within head (4) for receiving installation of high pressure and low pressure sensors (322) and (324) respectively. High pressure sensor (322) senses pressure within fluid passage (64), which connects inlet port (18) of regulator (10) with outlet port (218) of solenoid shut off valve (210) (see **Figures 13 and 14**). High pressure sensor (322), therefore, measures gas pressure entering regulator (10). In this respect, throughbore (326) connects sensor (318) to throughbore (329). On the other hand, low pressure sensor (324) senses pressure within outlet passage (300) and, therefore, measures gas pressure leaving the regulator assembly (10) and (110). In this respect, throughbore (328) connects sensor port (320) to outlet passage (300).

As illustrated in **Figure 5**, inlet port (18) communicates with high pressure gas stored in pressure vessel (216) through solenoid shut off valve (210). Solenoid shut off valve (210) controls gaseous flow out of pressure vessel (216). Solenoid shut off valve (210) includes an inlet port (220) and an outlet port (218). Outlet port (218) communicates with inlet port (18) of regulator (10) via

a fluid passage (64). A manual shut-off valve (330) (see **Figures 5 and 7**) is provided to interrupt flow between solenoid shut off valve (210) and inlet port (18).

In one embodiment, solenoid shut off valve (210) is an instant-on type valve. Referring to **Figure 8,** instant-on valve (210) includes a valve body (212) mounted at a distal end of neck (6). Valve body (212) includes an outlet port (218) and an inlet port (220). A flow passage (224) extends from the outlet port (218) and through the valve body (212) and is in communication with inlet port (220). A valve seat (226) is provided in flow passage (224). Valve seat (226) includes an orifice (228) provided at an inner end (230) of valve seat (226). Throughbore (329) extends between outlet port (218) and orifice (228) and forms part of flow passage (224).

Instant-on valve (210) is also provided with a sleeve (222). A primary piston (231) and a secondary piston (232) are disposed and slidably carried within sleeve (222), and are moveable therein. Sleeve (222) includes a first end (248) and a second end (250). First end (248) is open for communication with flow passage (224). Second end (250) includes a valve seat (252) with an orifice (254) formed therein. Sidewalls (251) extend from valve seat (252) and terminate at a distal end (253) whereby second end (250) is defined. Sleeve (222) communicates with pressure vessel (216) via orifice (254).

Secondary piston (232) includes a body (233) comprising a first end (234) and a second end (236). Secondary piston (232) is comprised of non-magnetic material. The first end (234) includes a sealing surface (238) for closing the orifice (228). The first end (234) is further characterized by a surface (235) exposed to gaseous pressure within pressure vessel (216). The second end (236) includes a valve seat (240) having an orifice (242). A bleed passage (244) is formed within body (233) and extends therethrough between the orifice (242) and an outlet port (246) provided at the first end (234). Outlet port (246) opens into flow passage (224), and particularly throughbore (329). Orifice (242) communicates with flow passage (224) via bleed passage (244). A sealing member (256), such as an o-ring, is carried at the periphery of body (233) between body (233) and sleeve

(222) thereby creating a seal to prevent gas from flowing between orifice (254) and first end (248) of sleeve (222).

Primary piston (231) is disposed behind secondary piston (232). Primary piston (231) includes a first end (258) and a second end (260). Primary piston (231) is comprised of magnetic material. First end (258) includes a first sealing surface (262) for closing orifice (242). Second end (262) includes a second sealing surface (264) for engaging valve seat (252), thereby closing orifice (254). Resilient member or spring (266) is provided behind primary piston (231) to bias primary piston (231) towards secondary piston (232) for pressing first sealing surface (262) against valve seat (240) and closing orifice (242). In one embodiment, spring (266) is housed at second end (250) of sleeve (222) and presses against second end (260) of primary piston (231).

Surrounding sleeve (222) is a solenoid coil (268). Solenoid coil (268) is provided to apply electromagnetic forces on primary piston (231) by external actuation, thereby causing movement of the primary piston (231) against the force of spring (266) and fluid pressure forces within sleeve (222).

Figures 8, 9 and 10 illustrate instant-on valve (210) in various conditions of operation. **Figure 8** illustrates instant-on valve (210) in a closed position. In this condition, solenoid coil (268) is not energized. Under these circumstances, spring (266) biases primary piston (231) towards secondary piston (232). In this respect, second sealing surface (264) is spaced from orifice (254) of valve seat (252) in sleeve (222), thereby opening orifice (254) to fluid pressure in the pressure vessel (216). Contemporaneously, first sealing surface (262) on primary piston (231) is pressed against valve seat (240) on secondary piston (232), thereby closing orifice (242). Because orifice (254) in sleeve (222) is open to fluid pressure in pressure vessel (216), the spaces between sleeve (222) and primary piston (231), and sleeve (222) and secondary piston (232) but below sealing member (256), are also exposed to fluid pressure of pressure vessel (216). Turning to secondary piston (232), first end (234) of secondary piston (232) is exposed to fluid pressure within pressure vessel (216) via inlet port (220). These fluid forces, acting downwardly upon secondary piston (232) are overcome by the

combined action of spring (266) and fluid pressure within sleeve (222), the latter forces being transmitted to secondary piston (232) by primary piston (231). As such, sealing surface (238) on secondary piston (232) is pressed against valve seat (226), thereby closing orifice (228).

Figure 9 illustrates instant-on valve (210) in a transition position. Instant-on valve (210) is in a transition position moments after solenoid coil (268) is energized. Moments after solenoid coil (268) is energized, electromagnetic forces produced thereby act upon primary piston (231) and overcome the forces exerted by spring (266) and gas pressure within sleeve (222), thereby causing second sealing surface (264) in primary piston (231) to seat against valve seat (252) provided on sleeve (222), thereby closing orifice (254). Simultaneously, first sealing surface (262) on primary piston (231) retracts from valve seat (240) of secondary piston (232), thereby opening orifice (242). By opening orifice (242) in secondary piston (232), gas contained within sleeve (222) begins to escape through bleed passage (244) within secondary piston (232) via orifice (242) and flow out of instant-on valve (210) through outlet port (218). As this happens, gas pressure within sleeve (222) begins to drop. However, under these conditions, fluid pressure in this region has not dropped sufficiently to unseat secondary piston (232) from valve seat (226). This is because the fluid forces acting on the surface of first end (234) of secondary piston (232), including fluid forces within throughbore (329), are still insufficient to overcome fluid forces within sleeve (222) acting upon the surface of second end (236) of secondary piston (232).

Figure 10 illustrates instant-on valve (210) in an open position. In this condition, fluid within sleeve (222) (below sealing member (256)) has further escaped through bleed passage (244) in secondary piston (232). At this point, gaseous forces acting behind the surface of second end (236) have sufficiently subsided to have become overcome by the fluid forces acting upon the surface of first end (234) of secondary piston (232). In response, sealing surface (238) of secondary piston (232) has become unseated from valve seat (226), thereby creating an uninterrupted flow path between the interior of pressure vessel (216) and outlet port (218) via fluid passage (224).

Referring to **Figures 5, 7, 11 and 13** pressure vessel (216) is filled with a gaseous mixture using module (2) through flow passages extending through instant-on valve (210). Gas enters module (2) via inlet port (331), passing through filter (334) (flow direction denoted by arrows (333) in **Figure 13**), and travelling through passage (329) for communication with the interior of pressure vessel (216) via orifice (228). Gas flowing through orifice (228) presses upon secondary piston (232), causing unseating of secondary piston (232) from valve seat (226) of flow passage (224). As a result, an uninterrupted flowpath is created between inlet port (331) and the interior of pressure vessel (216). When the filling operation is complete, spring (266) exerts sufficient force on primary piston (231), which is thereby transmitted to secondary piston (232), to cause secondary piston (232) to close orifice (228).

Figures 5, 7 and 12 illustrates the disposition of manual shut-off valve (330) within passage (329) between outlet port (218) and orifice (228), thereby permitting manual shut-off of fluid passage (224). In this respect, a passage (329) is provided within neck (6), extending from port (342) provided in head (4). Passage (329) includes a second valve seat (334) with an orifice (336) interposed between inlet port (18) of regulator (10) and orifice (228). Manual shut-off valve (330) includes a sealing surface (338) for seating against valve seat (334), thereby closing orifice (336) and blocking flow passage (224) such that communication between regulator (10) and instant-on valve (210) is interrupted. As such, manual shut-off valve (330) is co-axial with the fluid passage used to fill pressure vessel (216). Stem (340) extends from sealing surface (338) and through port (342) via passage (329). Manual actuator (344) is provided at distal end (346) of stem (340) to facilitate closing of flow passage (224) by manual intervention.

Other ports are provided in head (4) to facilitate operation of the above-described components of module (2) (see **Figure 13**). Thermally actuated relief device (348) can be provided within throughbore (352) to vent tank gases in the case of a fire to prevent explosions. Throughbore (352) vents to outlet connection (313) (see **Figures 13 and 14**). Port (354) is also provided with passage (356) extending therefrom, thereby functioning as a wire pass through and permitting electrical connection of instant-on valve (210) exterior to the pressure vessel (216).

As illustrated in **Figures 1, 5 and 7**, module (2) is adapted for mounting within nozzle (217) of pressure vessel (216). Nozzle (217) is characterized by an aperture (227) having a longitudinal axis (221). Head (4) extends outside nozzle (217) and, therefore, functions as a cap. Neck (6) depends from head (4) and extends into the interior (219) of pressure vessel (216). In this respect, when module (2) is mounted within nozzle (217) in this manner, each of the regulators (10) and (110) and solenoid shut-off valve (210) are disposed within the interior of (219) of pressure vessel (216). Also, each of moveable pressure boundary members (31) and (131) are oriented such that each of their respective transverse axis (61) and (161) are substantially perpendicular to longitudinal axis (62) of neck (6) or longitudinal axis (221) of aperture (227). As a further incident, each of moveable pressure boundary members (31) and (131) lies or is disposed substantially in a plane which is parallel to the longitudinal axis (62) of neck (6) or the longitudinal axis (221) of aperture (227).

Although the disclosure describes and illustrates preferred embodiments of the invention, it is to be understood that the invention is not limited to these particular embodiments. Many variations and modifications will now occur to those skilled in the art. For definition of the invention, reference is to be made to the appended claims.

CLAIMS:

1. A gas flow regulation module comprising:

a body, including a longitudinal axis, and including a first port and second port, a first fluid passage extending from the first port, and a second fluid passage extending from the second port; and

a regulator, mounted to the body and disposed in communication with the first and second fluid passages, including a moveable pressure boundary member characterized by a transverse axis which is substantially perpendicular to the longitudinal axis of the neck.

2. The gas flow regulation module claimed in claim 1, wherein the regulator comprises:

a housing, with an internal surface, including a pintle chamber and an output chamber;

a moveable pressure boundary member extending across the internal surface of the housing;

a valve seat, including an orifice, wherein the pintle chamber can communicate with the output chamber via the orifice; and

a pintle valve, mounted to the moveable pressure boundary member, and including a sealing member, and moveable into contact with the valve seat to thereby close the orifice and isolate the pintle chamber from the output chamber.

3. The gas flow regulation module as claimed in claim 1, wherein the regulator comprises at least two stages.

4. The gas flow regulation module as claimed in claim 1, wherein the moveable pressure boundary member is a diaphragm assembly.

5. The gas flow regulation module as claimed in claim 1, further comprises a solenoid shut-off valve, mounted to the body, and including a sealing member for closing the second port.

6. The gas flow regulation module as claimed in claim 5, further comprising a third port extending to the second port via a third fluid passage.

7. A gas flow regulation module comprising:

a body, including a longitudinal axis, and including a first port and a second port, a first fluid passage extending from the first port, and a second fluid passage extending from the second port; and
a regulator, mounted to the body and disposed in communication with the first and second fluid passages, including a moveable pressure boundary member substantially disposed in a plane which is substantially parallel to the longitudinal axis of the neck.

8. The gas flow regulation module claimed in claim 7, wherein the regulator comprises:

a housing, with an internal surface, including a pintle chamber and an output chamber;
a moveable pressure boundary member extending across the internal surface of the housing;
a valve seat, including an orifice, wherein the pintle chamber can communicate with the output chamber via the orifice; and
a pintle valve, mounted to the moveable pressure boundary member, and including a sealing member, and moveable into contact with the valve seat to thereby close the orifice and isolate the pintle chamber from the output chamber.

9. The gas flow regulation module as claimed in claim 7, wherein the regulator comprises at least two stages.

10. The gas flow regulation module as claimed in claim 7, wherein the moveable pressure boundary member is a diaphragm assembly.

11. The gas flow regulation module as claimed in claim 1, further comprises a solenoid shut-off valve, mounted to the body, and including a sealing member for closing the second port.

12. The gas flow regulation module as claimed in claim 5, further comprising a third port extending to the second port via a third fluid passage.

13. A gas flow regulation module, adapted for mounting within a pressure vessel and through an aperture provided in the pressure vessel, the pressure vessel including an interior, the aperture including a longitudinal axis, comprising:

a body, including a first port and a second port, a first fluid passage extending from the first port and a second fluid passage extending from the second port; and
a regulator mounted to the body and disposed in the interior of the pressure vessel and in communication with the first and second fluid passages, including a moveable pressure boundary member characterized by a transverse axis which is perpendicular to the longitudinal axis of the aperture.

14. The gas flow regulation module claimed in claim 1, wherein the regulator comprises:

a housing, with an internal surface, including a pintle chamber and an output chamber;
a moveable pressure boundary member extending across the internal surface of the housing;
a valve seat, including an orifice, wherein the pintle chamber can communicate with the output chamber via the orifice; and
a pintle valve, mounted to the moveable pressure boundary member, and including a sealing member, and moveable into contact with the valve seat to thereby close the orifice and isolate the pintle chamber from the output chamber.

15. The gas flow regulation module as claimed in claim 13, wherein the regulator comprises at least two stages.

16. The gas flow regulation module as claimed in claim 13, wherein the moveable pressure boundary member is a diaphragm assembly.

17. The gas flow regulation module as claimed in claim 13, further comprises a solenoid shut-off valve, mounted to the body, and including a sealing member for closing the second port.

18. The gas flow regulation module as claimed in claim 13, further comprising a third port extending to the second port via a third fluid passage.

19. The gas flow regulation module as claimed in claim ~~8~~ 18, further comprising a third port extending to the second port via a third fluid passage.

20. A gas flow regulator module, adapted for mounting within a pressure vessel, and through an aperture provided in the pressure vessel, the pressure vessel including an interior, a longitudinal axis, comprising:

a body, including a first and a second port, a first fluid passage extending from the first port, and a second fluid passage extending from the second port; and
a regulator mounted to the body and disposed in the interior of the pressure vessel and in communication with the first and second fluid passages, the regulator including a moveable pressure boundary member substantially disposed in a plane which is substantially parallel to the longitudinal axis of the aperture.

21. The gas flow regulation module claimed in claim 20, wherein the regulator comprises:

a housing, with an internal surface, including a pintle chamber and an output chamber;
a moveable pressure boundary member extending across the internal surface of the housing;

a valve seat, including an orifice, wherein the pintle chamber can communicate with the output chamber via the orifice; and

a pintle valve, mounted to the moveable pressure boundary member, and including a sealing member, and moveable into contact with the valve seat to thereby close the orifice and isolate the pintle chamber from the output chamber.

22. The gas flow regulation module as claimed in claim 20, wherein the regulator comprises at least two stages.

23. The gas flow regulation module as claimed in claim 20, wherein the moveable pressure boundary member is a diaphragm assembly.

24. The gas flow regulation module as claimed in claim 20, further comprises a solenoid shut-off valve, mounted to the body, and including a sealing member for closing the second port.

25. The gas flow regulation module as claimed in claim ~~20~~ 25, further comprising a third port extending to the second port via a third fluid passage.

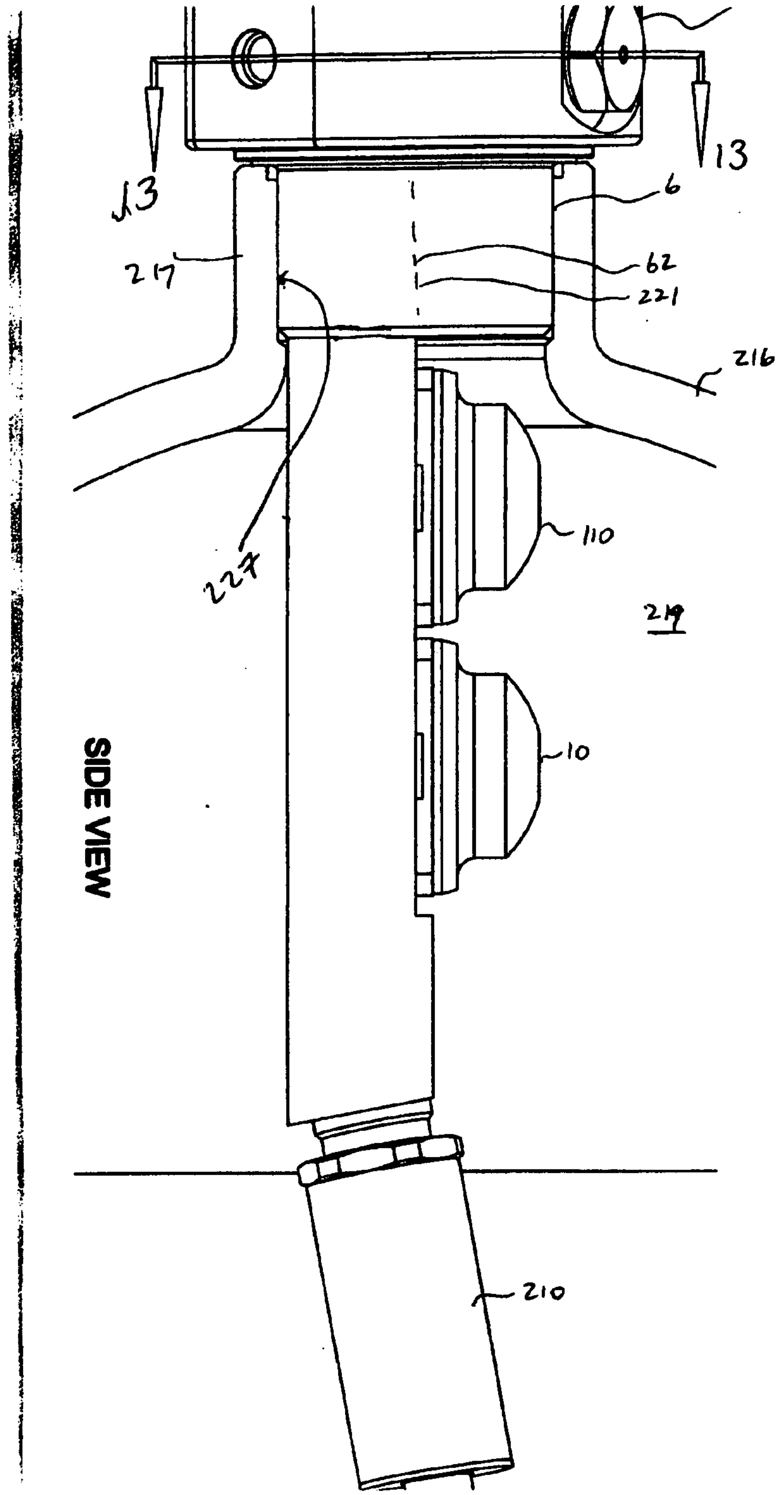

FIGURE 1

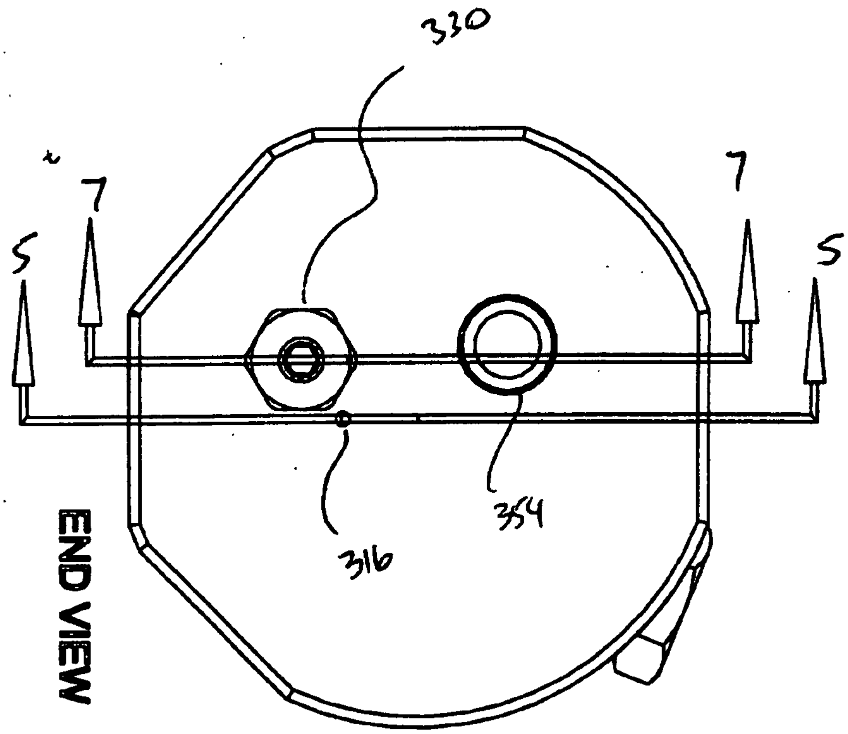

FIGURE 2

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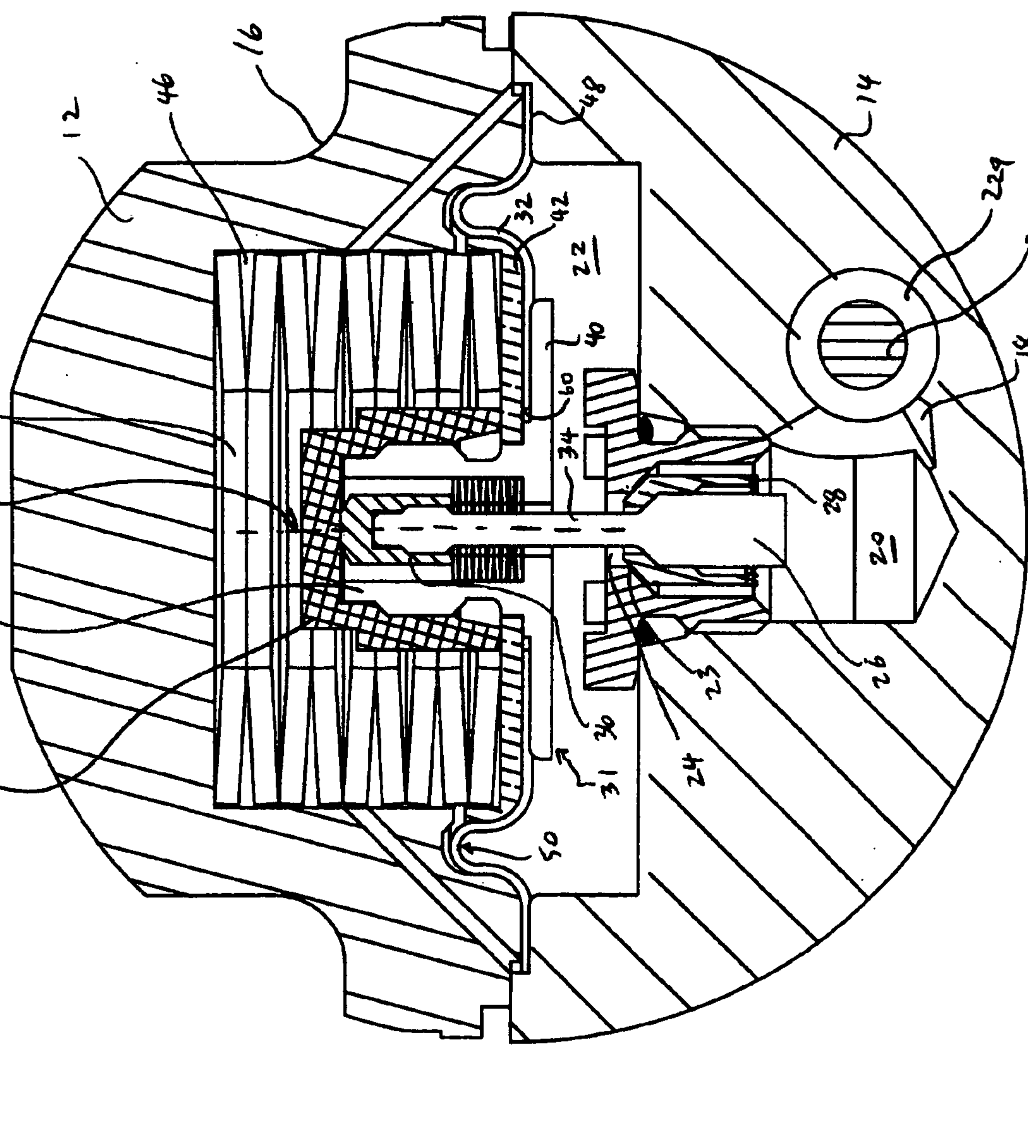
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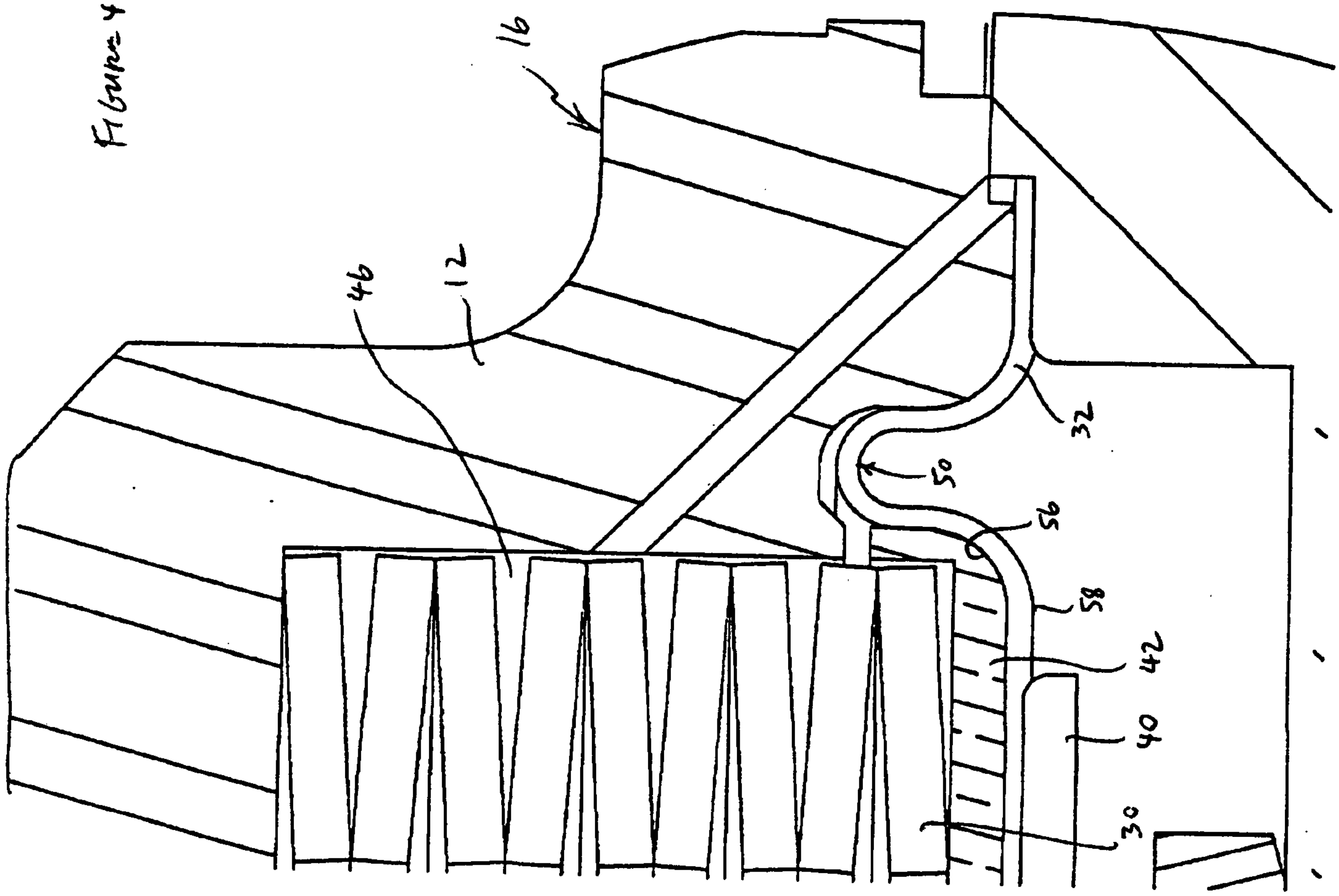
FIGURE 3

Figure 4



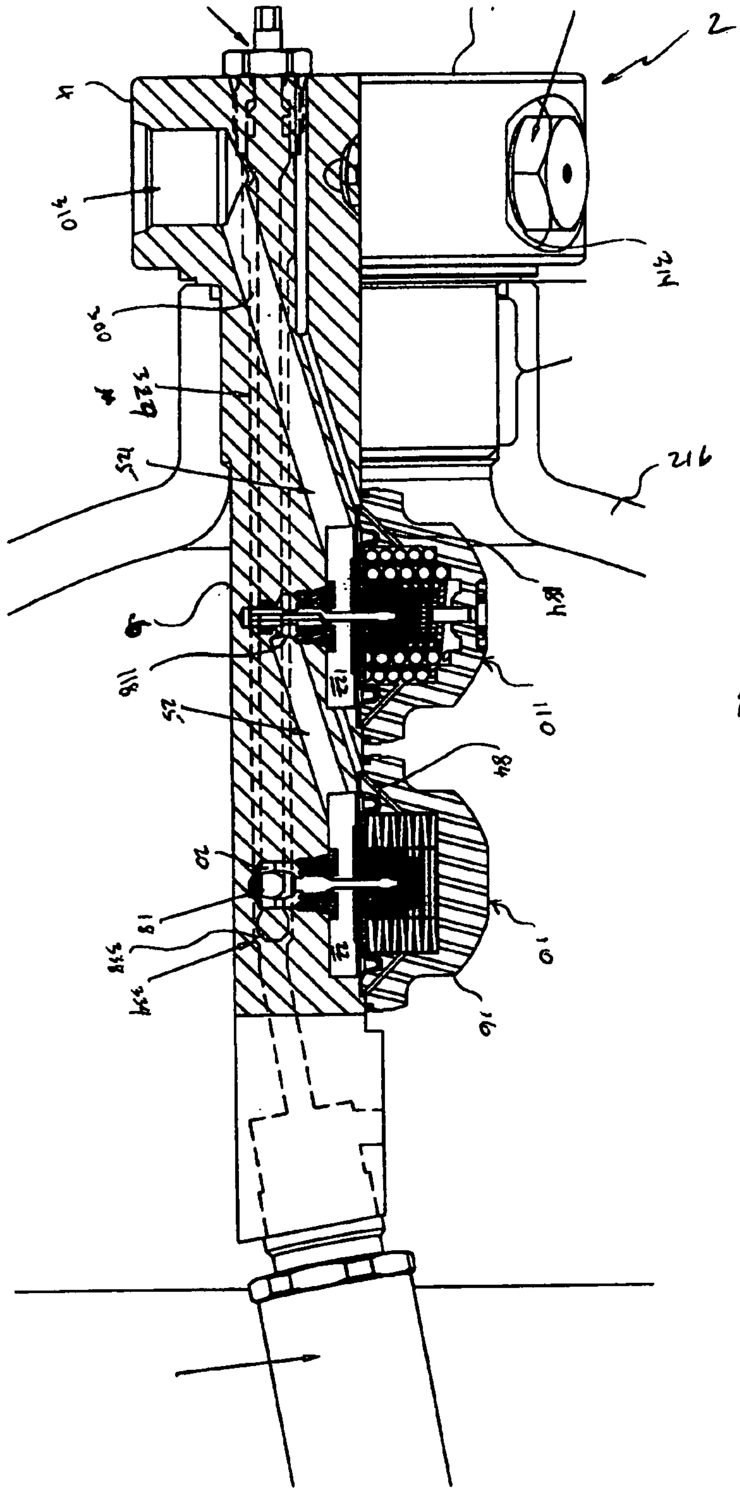


Figure 5

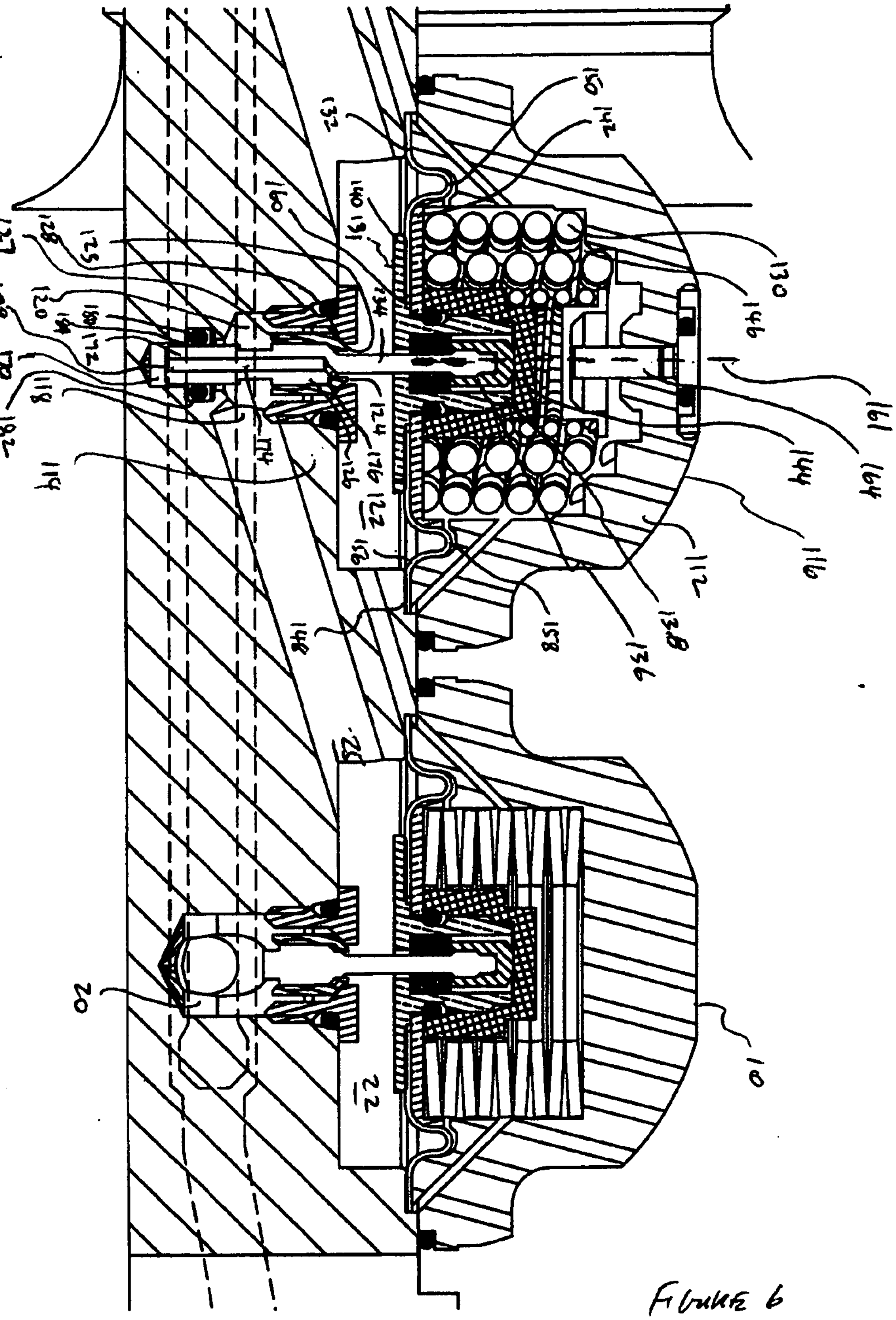


FIGURE 6

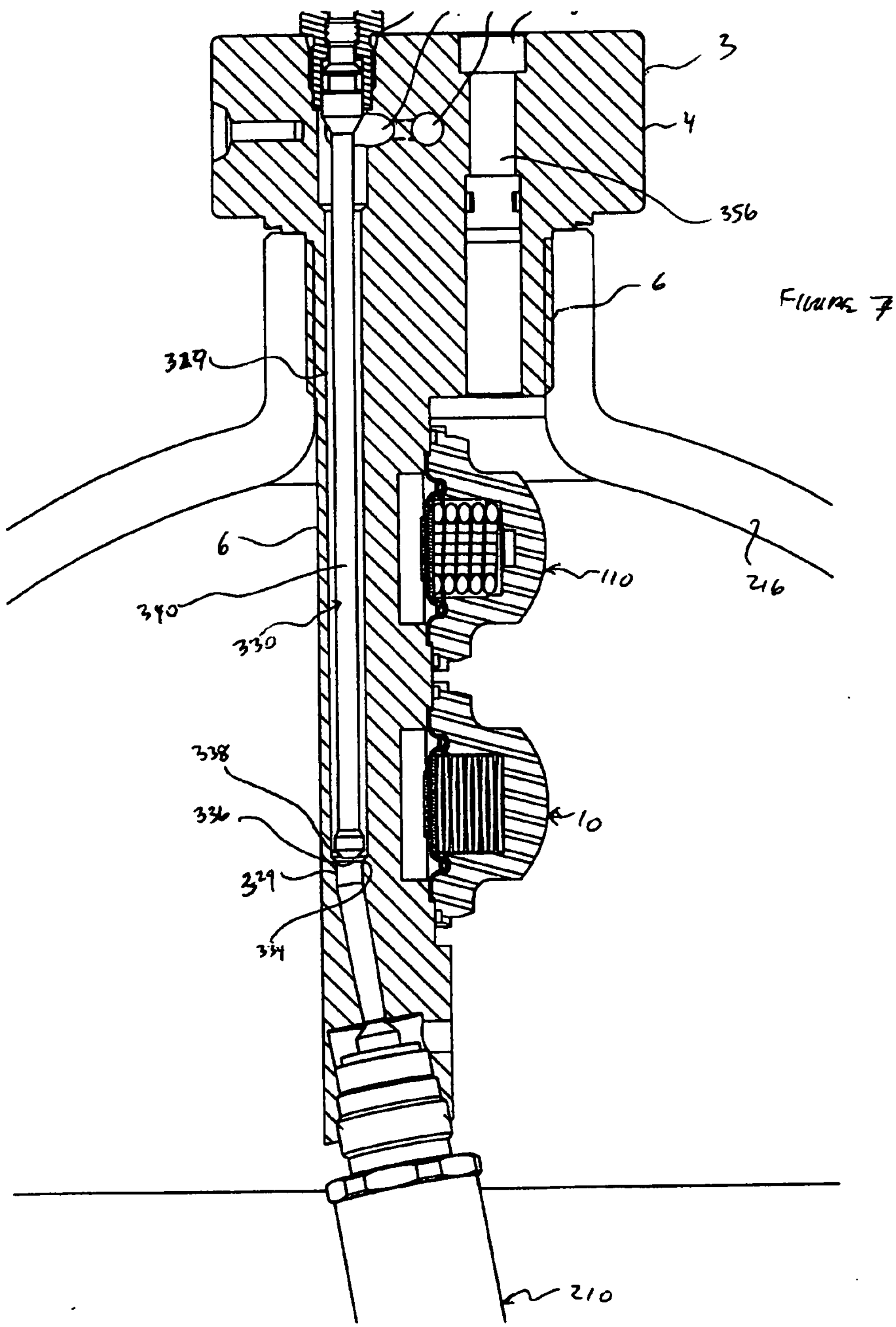

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Figure 7
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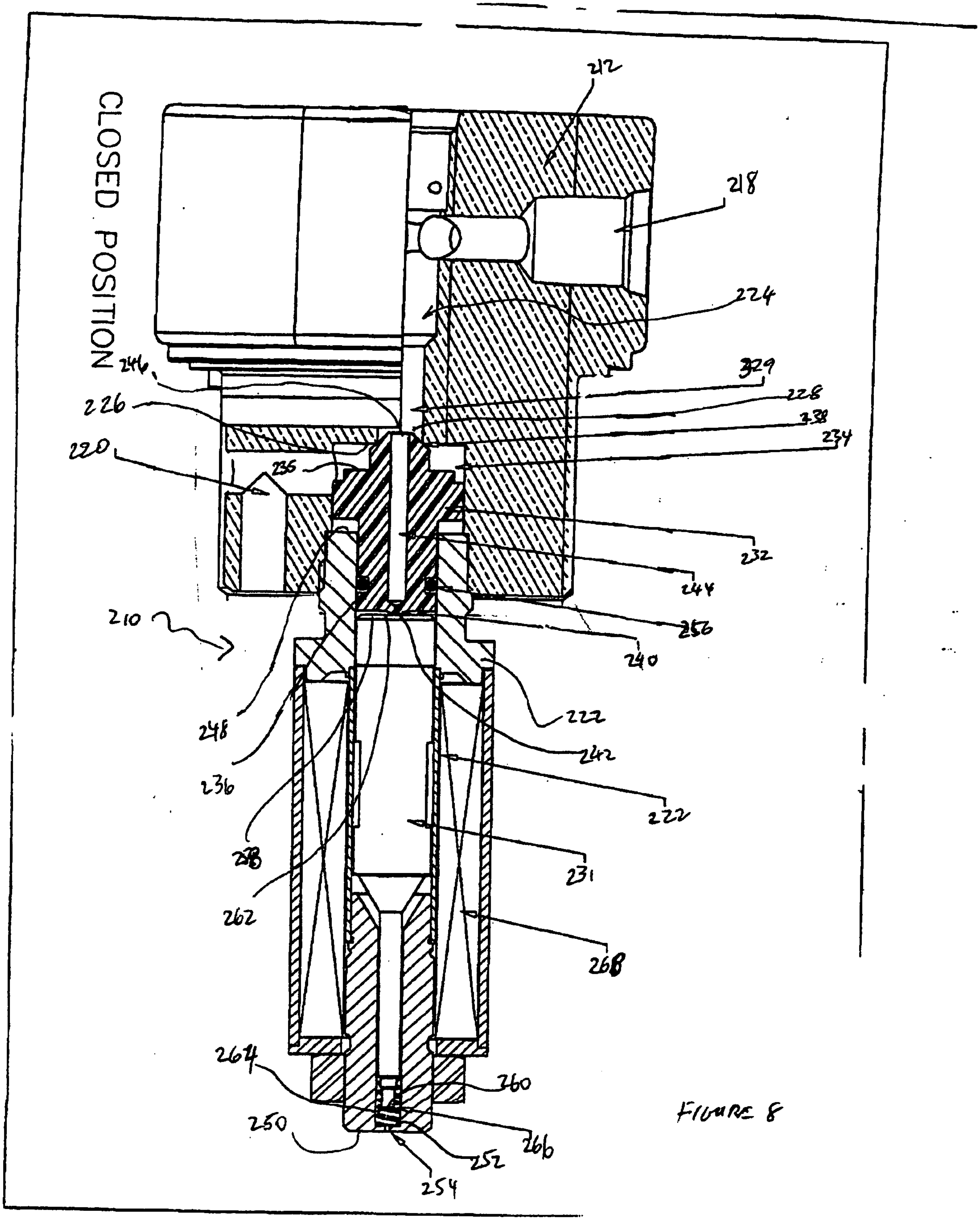
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FIGURE 8

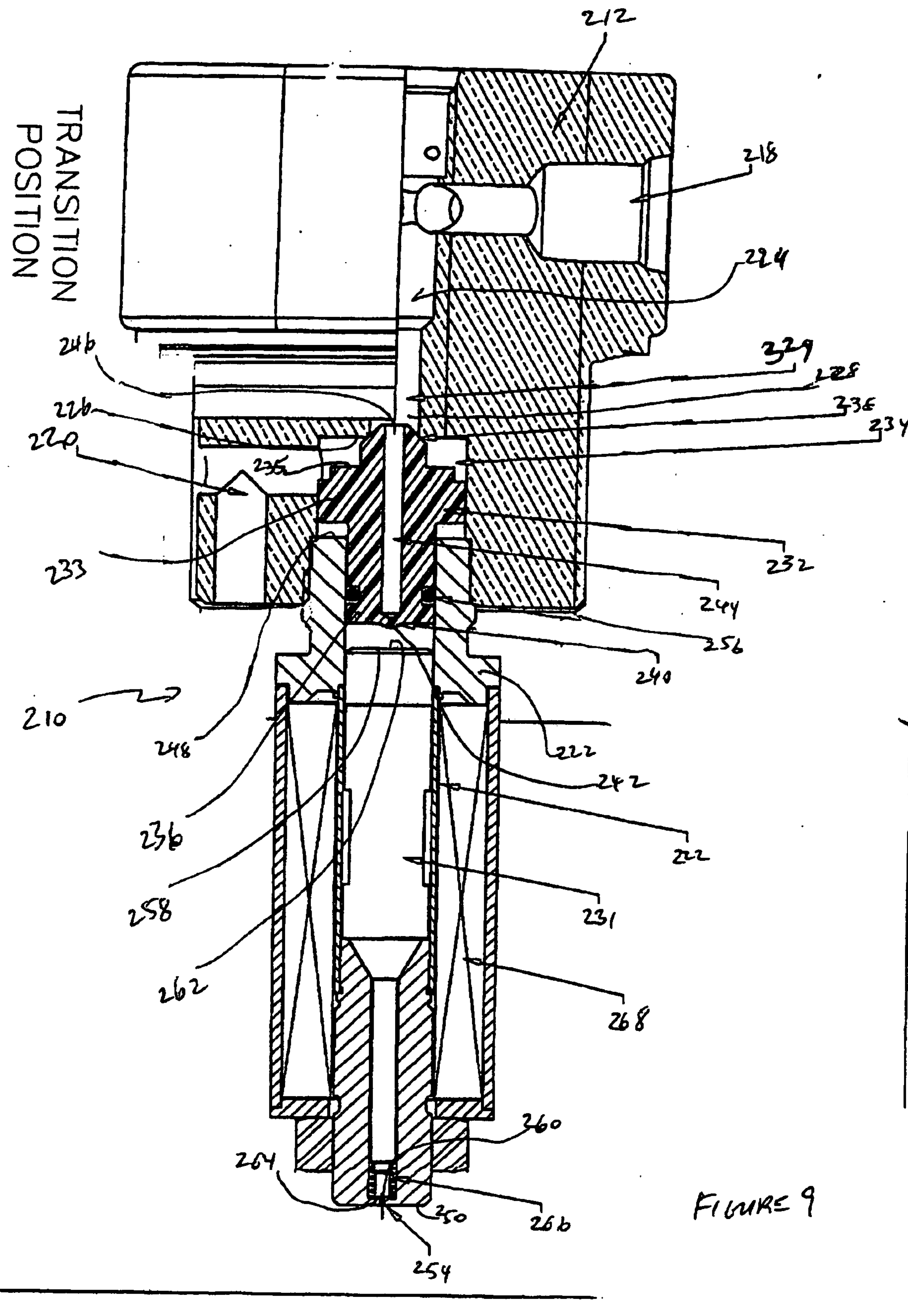
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FIGURE 9

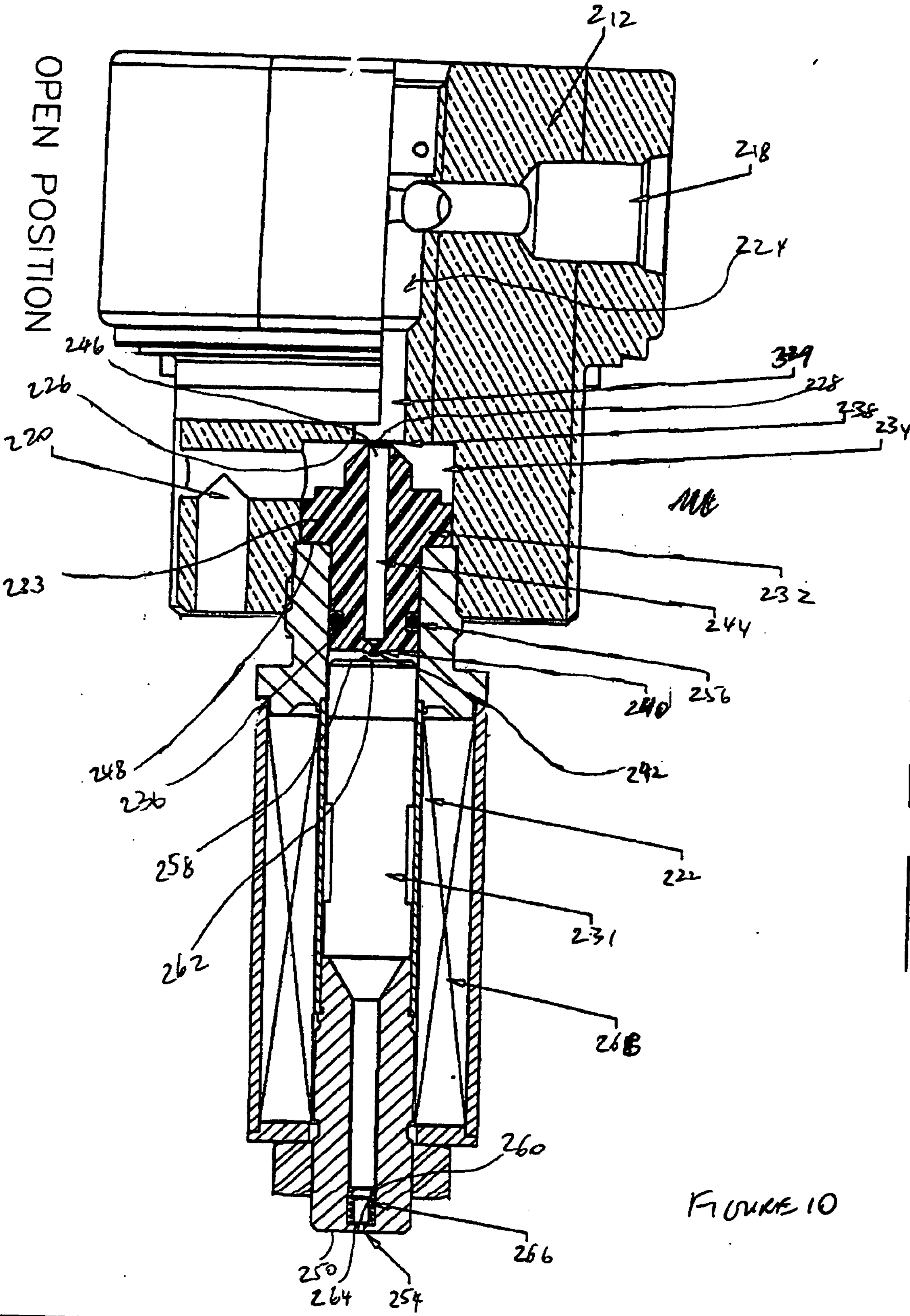
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FIGURE 10

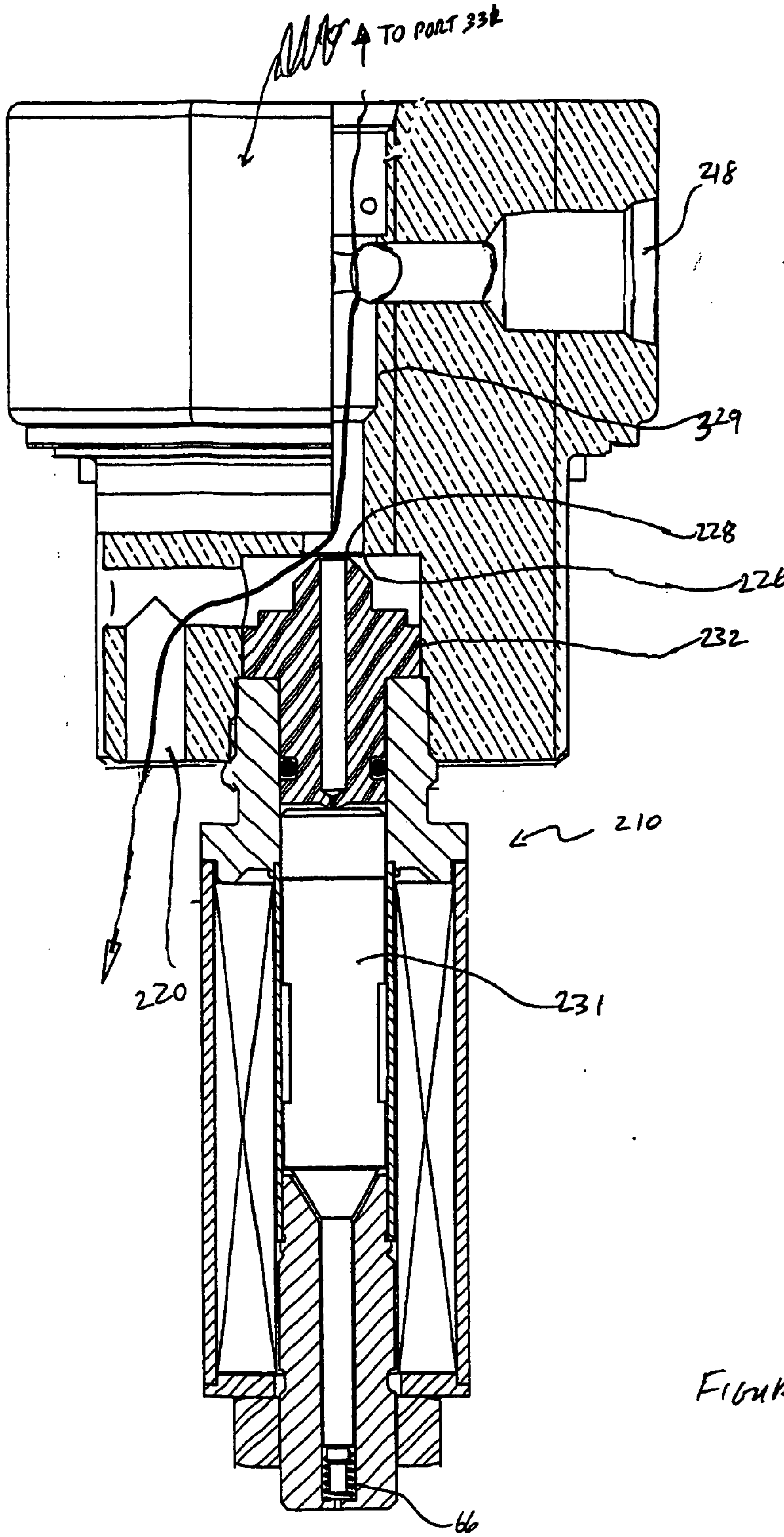

FIGURE 11

FILLING

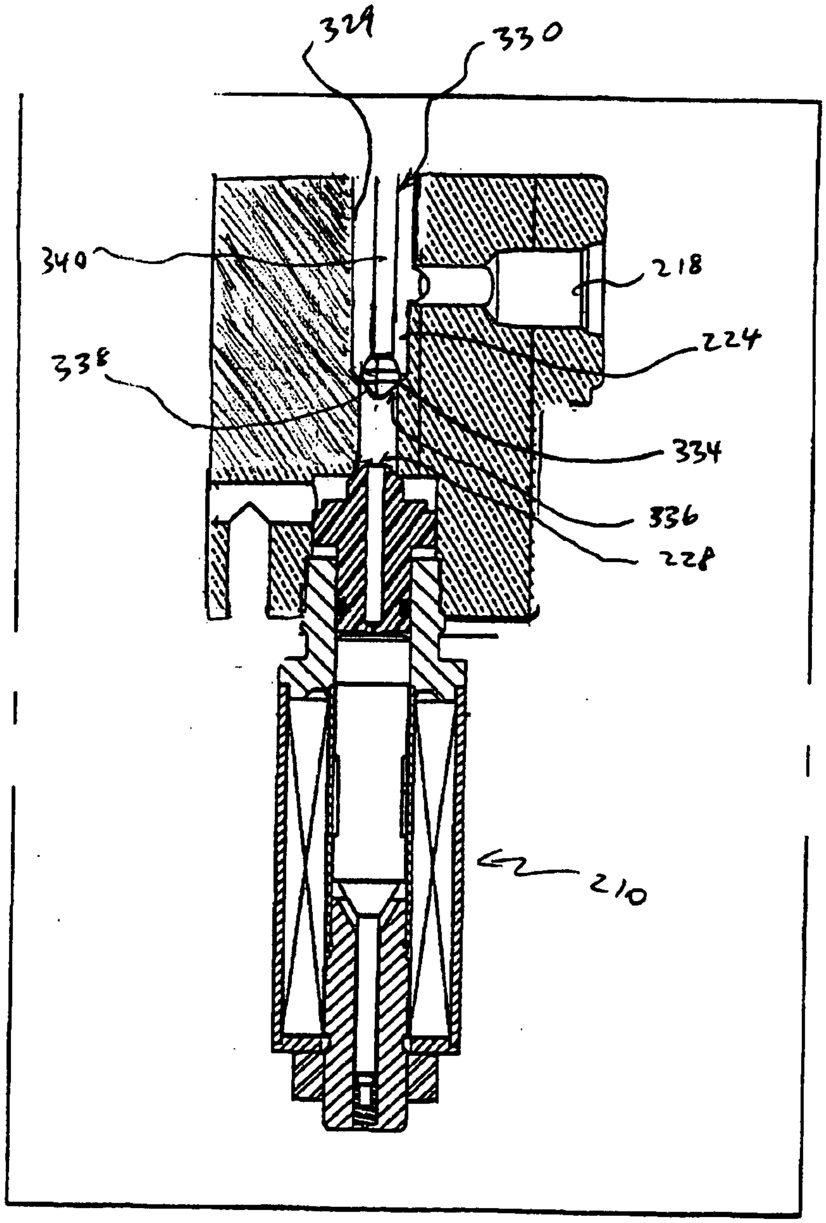

FIGURE 12

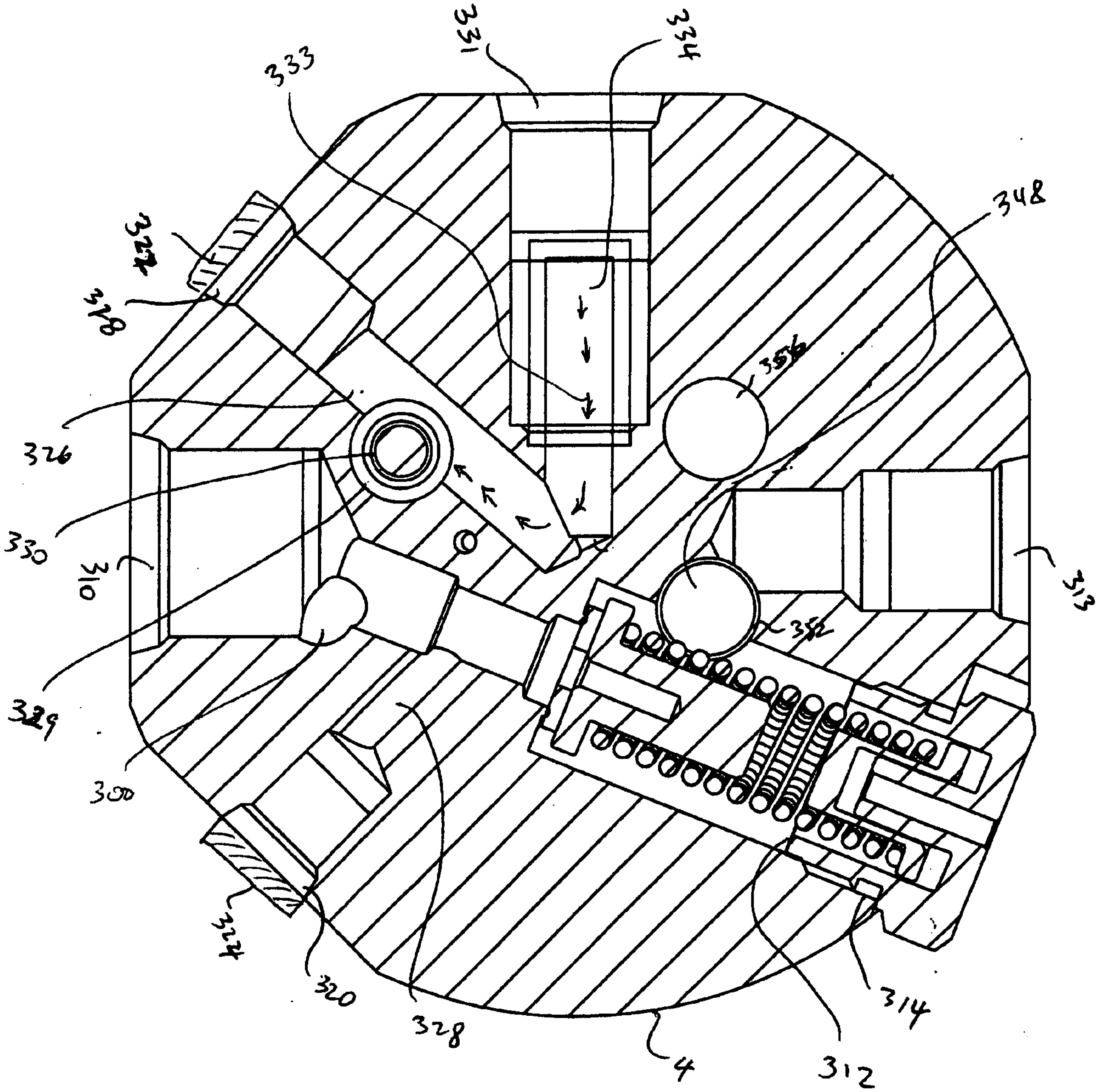
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FIGURE 13

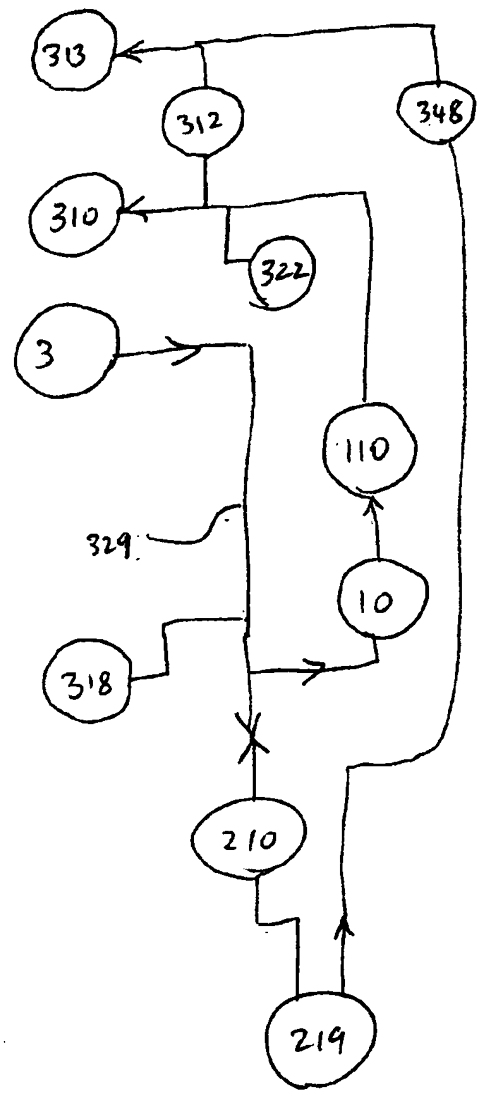

FIGURE 14